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THE RESPIRATORY SYSTEM IN THE NORMAL WHITE PEKIN DUCK

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The Respiratory System in the Normal White Pekin Duck

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THE observations in this paper have resulted from a study of neoplasms induced with a carcinogenic agent in the respiratory tract of the white Pekin duck (Rigdon, 1957). The anatomical findings in the duck's respiratory tract have made it necessary to establish the normal for this bird. The respiratory system in the white Pekin duck is similar to that in other birds; however, there are some interesting variations when compared with similar structures in the chicken (McLeod and Wagers, 1939) and in the turkey (Cover, 1953; Rigdon *et al.*, 1958). Some of these differences no doubt reflect physiologic functions.

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The respiratory tract in the bird has been studied extensively by Sappey (1847), Chauveau (1890), Bradley (1915), Locy (1916), Kaupp (1918), Gilbert (1939), Zietzschmann (1943), and Hazelhoff (1951). Sappey in 1847 gave an excellent description of the respiratory apparatus and emphasized certain variations in different types of birds. A large part of Sappey's monograph is devoted to a review of the literature, beginning with the observations made by Aristotle about 400 B.C. and including those of John Hunter in 1774. Harvey in 1651 was the first to describe carefully the air sacs. Juillet in 1911 published a treatise on the anatomical, embryological, histological, and comparative study of the bird's lung.

Few anatomical observations have been made on the respiratory tract in the duck (Chauveau, 1890; and McLeod and

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Wagers, 1939); however, the mechanism of respiration in the duck has been studied by several investigators (Sappey, 1847; Huxley, 1913; Orr, 1913; Paton, 1913; and Dooley and Koppanyi, 1929). McLeod and Wagers (1939) have an excellent discussion of the respiratory system in the chicken. They describe the nasal cavity, the infraorbital sinus and the pharynx and also give a detailed discussion of the larynx. McLeod and Wagers (1939) make several casual references to some of the variations observed in the duck as compared with those in the chicken. They note that the infraorbital sinus is larger in its anterior part and its opening is on a lower level and somewhat larger than that of the chicken. These investigators point out that in the male duck "a remarkable spherical bony box complicates the structure of the syrinx" which is called the *bulla tympaniformis*. Another interesting feature in the paper of McLeod and Wagers (1939) is the description of the respiratory system referable to other anatomic structures.

DEMONSTRATION OF THE AIR SACS

Latex* was used to inject the respiratory tract. The birds were sacrificed and a cannula was put into the proximal third of the trachea. The head of the duck was attached to a ring-stand. A funnel filled with latex was placed approximately 12 inches above the level of the head and it connected by a rubber tube to the cannula. When the latex ceased to enter, the trachea was ligated and the duck was removed from the ring-stand. The tail was elevated over the head permitting the latex to fill the air sacs in the cervical region. The air normally present in the abdominal air sacs, when the latex entered, escaped into the cervical and clavicular air sacs during the time of the injection. The presence of this air interfered with the filling of these air sacs with the latex.

After the feathers were partially removed from the posterior surface of the body, the duck was put into a container with a 4 percent solution of formaldehyde and a 4 percent solution of acetic acid. After a few hours in this fixative more of the skin and feathers were removed to permit better preservation. After 24 hours fixation the remaining feathers and portions of the wings and legs were removed. After 5 to 7 days the muscles were carefully dissected to demonstrate the latex in the air sacs.

A circumscribed area in the cervicothoracic region protrudes when pressure is applied to the abdomen (Figure 1). This area recedes when the pressure is removed. When the sternum and adjacent ribs are removed large spaces are present in the thoracic and abdominal cavities. These are the air sacs.

The lungs are present on each side of the thoracic cavity. There is no muscular diaphragm separating the lungs from the abdominal viscera only a thin membrane. The lungs are bound to the thoracic wall by fibrous adhesions and small muscles (Figure 2–6). These structures can be easily broken by blunt dissection and the lungs removed. The muscles are small and fan-shaped, extending from the ribs to the pleura and attached to the ribs along a line at the margin of the lung, extending 6 to 8 mm. over the surface of the lungs (Figure 2–5). In the area of the apex of each lung there is a muscle attached to the pleura and the inferior surface of the sternum. It measures approximately 25 mm. in length and 2–4 mm. in width (Fig. 2–7).

The posterior inferior surface of each lung is located at the anterior border of the abdominal air sacs (Figure 3–6). The

* Polson Rubber Co., Garrettsville Ohio.

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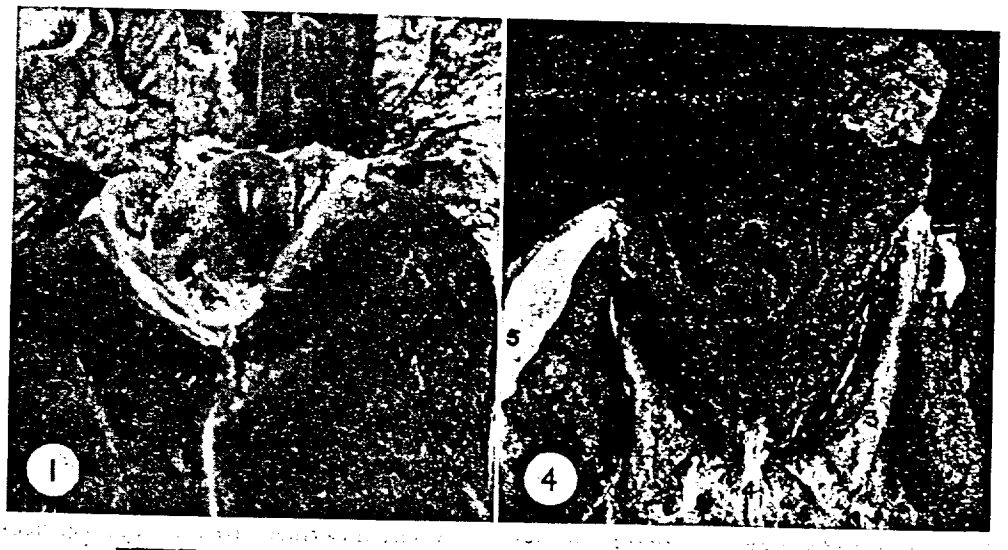

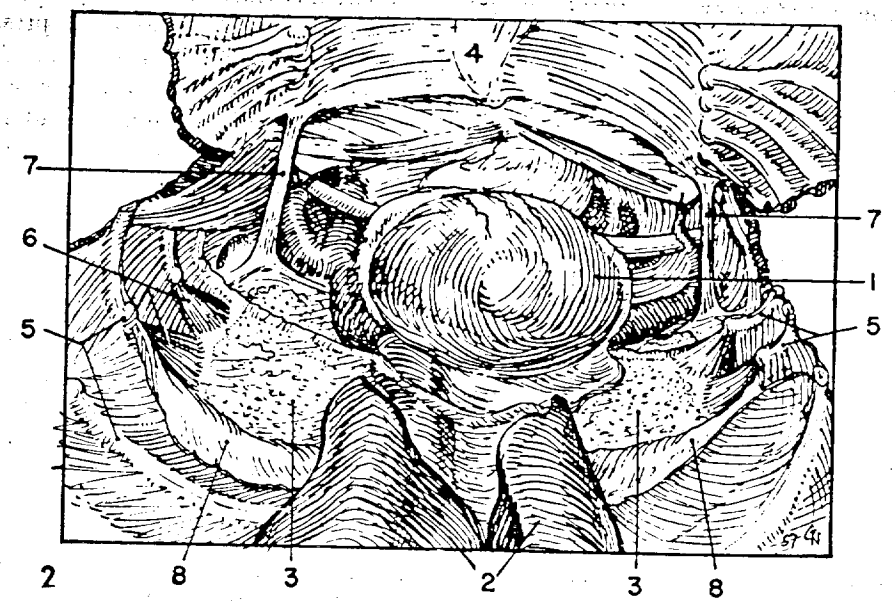

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lesser abdominal air sac (Figure 3–6) is second in size to the greater abdominal air sac. It is located near the middle part of the lateral abdominal wall. The abdominal wall is lateral to this air sac and the greater abdominal air sac is medial. There are no diverticula from this air sac. The greater abdominal air sac (Figure 3–5) is the largest air sac in the duck, extending posteriorly the entire length of the abdominal cavity. Diverticula extend from the posterior superior surface of this air sac into the spaces about the head of the femur. The thoracic air sac is located at the inferior margin of the lung (Figure 3–7). The clavicular and cervical air sacs fill the anterior portion of the thoracic cavity (Figures 4 and 5). Diverticula from the periphery of the clavicular air sac extend out between the adjacent muscles and the subcutaneous tissue (Figure 2–4). The thoracic air sac on the right is larger than the corresponding air sac on the left (Figures 6–7). The cervical air sac on the right also is larger than its counterpart on the left (Figure 5). The posterior diverticulum is more conspicuous on the right cervical air sac than it is on the left. There is a single communication between the lung, the greater and the lesser abdominal air sacs on each side of the body. In the thoracic air sac there are 2 communications with the lung. In the clavicular air sac there are 2 or 3 communications with the lung. Only one communication is present between the cervical air sac and the lung (Figure 7). There are no communications with each other between the different air sacs on a single side of the duck; however, the cervical air sac communicates with its counterpart on the opposite side through the cervical vertebrae and the clavicular air sac is continuous with its counterpart on the opposite side across the midline.

There is a communication between the clavicular air sac and the humerus through the *Foramen pneumaticum* which is located on the medial side of the proximal end of this bone (Figure 8). This foramen measures 1.5 cm. in diameter in the adult duck. There are many communications between the clavicular air sac and the sternum. Sometimes latex is present in the ribs near their attachment to the sternum. The cervical air sac communicates directly with the cervical vertebrae. Apparently this latex extends down from the cervical and thoracic vertebrae to infiltrate the lumbo-sacral mass (Figure 9). The thoracic vertebrae are diffusely infiltrated with latex. There are small collections of latex between the vertebrae on the anterior lateral surfaces. These collections are continuous with the latex within the vertebrae (Figure 10–2). There

FIG. 1. A circumscribed area is present in the cervico-thoracic area, after the feathers and skin are removed, that protrudes when pressure is applied to the abdomen. This area recedes when the pressure is removed.

FIG. 2. Drawing of thorax of the duck to show the small muscles (6 and 7) that extend from the pleural surface of the lungs to the bony thorax: (1) heart (2) liver, (3) lungs, (4) sternum-posterior surface, (5) ribs, (6) muscles between ribs and lung, (7) muscle between apex of lung and posterior surface of sternum, (8) wall of lesser abdominal air sac.

FIG. 3. Latex-filled respiratory tract of an adult white Pekin duck showing the left side: (1) trachea, (2) lung, (3) cervical air sac, (4) clavicular air sac, (5) greater abdominal air sac, (6) lesser abdominal air sac, (7) thoracic air sac.

FIG. 4. Latex-filled cervico-thoracic area in the duck with clavicular and pectoral muscles removed: (1) clavicular air sac, (2) axillary diverticula from the clavicular air sac, (3) coracoid bone, (4) sternum, (5) humerus, (6) cervical vertebrae, (7) trachea.

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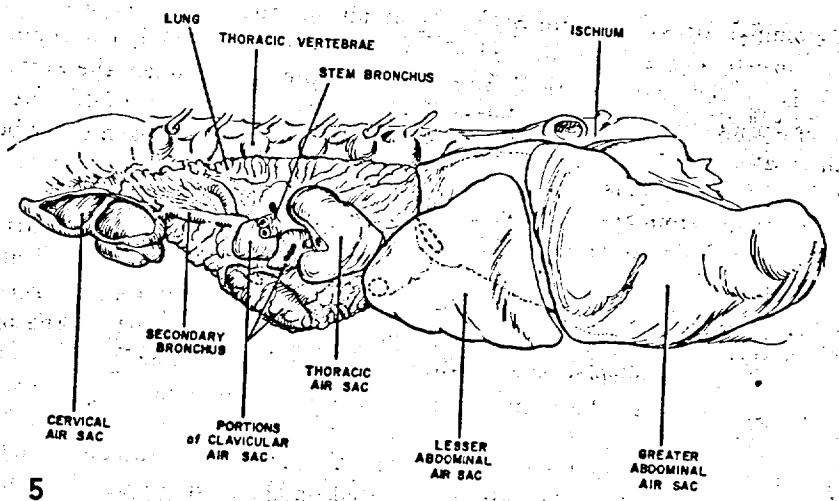

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are 2 latex-filled spaces of moderate size on each side of the midline in the area of the anterior portion of the lumbo-sacral vertebral mass (Figure 10–1). No latex has been observed within the lumen of the femur, the coracoid or the scapula.

OBSERVATIONS ON THE ANATOMIC AND HISTOLOGIC FEATURES OF THE RESPIRATORY TRACT

The trachea in the duck lies between the external larynx that opens into the oral cavity and its bifurcation which is located within the thoracic cavity (Figure 11). A circular cartilagenous enlargement is present in the male at the lower end of the trachea. This is the internal larynx or the syrinx (Figure 12-B). The external larynx is represented by a slit-like opening, the glottis located in the pharynx just posterior to the base of the tongue (Figure 13). The wall of the trachea is supported by cartilagenous rings which ossify during the first year of life. The trachea is lined by ciliated pseudostratified epithelium and has many mucin-secreting cells (Figure 14). Approximately one-fourth of the circumference of the trachea is lined by a cuboidal type of epithelium with no intervening mucin-secreting cells (Figure 15). Few lymphocytes are present in the fibrous tissue stroma between the lining epithelium and the cartilageous rings of the trachea. Sometimes aggregates of lymphocyte form small nodules in this stroma (Figure 16).

The right and the left bronchus are approximately 2–3 cms. in length. After entering the lung parenchyma the bronchi divide into primary. secondary, and tertiary or parabronchi. In some portion of the lung the larger bronchi are readily seen on the pleural surface (Figure 3–2). Some of the larger bronchi extend directly through the lung to communicate with the air sacs (Figure 7). The primary and secondary bronchi usually progressively decrease in size. The tertiary or parabronchi have a more or less uniform diameter throughout their entire length (Figure 17). Some of the parabronchi terminate as large spaces on the pleural surface of the lung (Figure 18), while others communicate with each other. A parabronchus and the adjacent air capillaries form the basic respiratory unit in the duck. These units usually form a 5 or 6 sided prism (Figure 19). In our latex-injected specimen the air capillaries did not fill.

The primary and secondary bronchi are lined by columnar epithelial cells similar to those in the trachea. A narrow band of smooth muscle is present about the larger bronchi and it continues into the wall of the parabronchi. Muscle is also present about the terminal dilatations of the parabronchi at the periphery of the lung. The parabronchi (Figure 20) and the small air capillaries are lined by endothelial-like cells (Figure 21–22). The spaces at the surface of the lung formed by the parabronchi (Figure 18) are also lined by either cuboidal or columnar epithelium. The stroma about the terminal

FIG. 5. Drawing to show the air sacs in their relation to the lungs.

FIG. 6. Latex-filled air sacs in the duck. Anterior view with sternum and viscera removed: (1) trachea, (2) syrinx in male duck, (3) bronchi, (4) clavicular air sac, (5) lesser abdominal air sac right, (6) portion of the right greater abdominal air sac (the greater part of this sac has been removed), (7) right thoracic air sac, (8) small air sac on left bronchus, (9) left lesser abdominal air sac, (10) coracoid bone, (11) axillary diverticulum from clavicular air sac, (12) cervical air sac, left.

FIG. 7. Latex-filled ventral bronchi showing a communication of one bronchus with cervical air sac (A)

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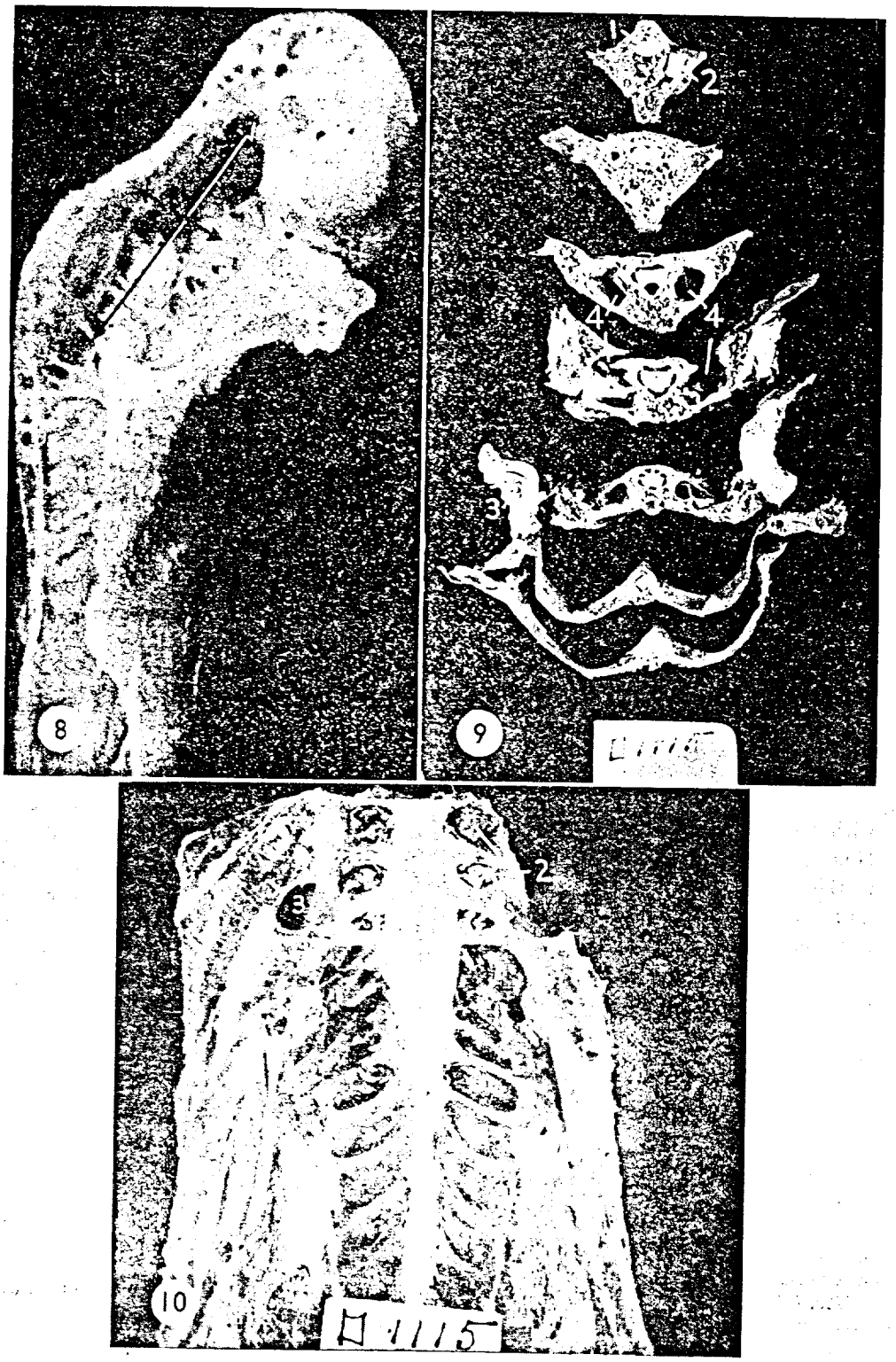

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parabronchi is loose connective tissue. Only a few fibroblasts and a small amount of fat are present in this area of the lung. Small spaces lined with endothelial-like cells are suggestive of lymphatic channels.

To study the blood capillaries in the lung, an adult bird was sacrificed and saline was immediately injected into the pulmonary artery. When the saline returned through the pulmonary veins free of red cells, India ink was injected into the pulmonary artery. When the ink returned through the pulmonary veins, the entire carcass was fixed immediately in a 4 percent solution of formaldehyde. Sections of the lung were prepared by the paraffin technique for histologic study.

There are numerous blood capillaries about the small air spaces in the lung of the duck (Figure 23). These unite to form small vessels within the respiratory unit and then pass to the interlobular spaces uniting with the vessels from the adjacent lobules. Many cross sections of nerves are present in the histologic sections of the lung. Small ganglia are also present. It is of interest to find in the osmic acid stains that all the nerve fibers are not myelinated. Pacinian corpuscle is sometimes demonstrated in the wall of the trachea (Figure 24). An occasional microscopic mass of osteoid tissue is present in the lungs.

DISCUSSION

There are 9 air sacs in the white Pekin duck; the clavicular is single while the cervical, thoracic, lesser and greater abdominal air sacs are in pairs. The number of air sacs in the duck corresponds with that given by McLeod and Wagers (1939) for the chicken. In the turkey, Cover (1953) and Rigdon *et al.* (1958) found only 7 air sacs. The terminology used for the different air sacs in birds varies (McLeod and Wagers, 1939).

In the duck, the humerus, sternum and vertebrae are pneumatized. The humerus and sternum communicate with diverticula from the clavicular air sac, while the cervical vertebrae are in direct communication with the cervical air sacs. Apparently air diffuses from the cervical vertebrae in the duck into the other parts of the vertebral column. Kaupp, in 1918, pointed out that the cervical air sac furnished air to all the cervical and dorsal vertebrae and to all the vertebral ribs. He also said the air "after passing through the first vertebra, leaves by a lateral exit to enter a small air sac. From this it passes into the superior part of the second vertebra escapes from this through its lower portion, to be received into a lateral sac and so on to the last dorsal vertebra." In the duck the air continues from the last dorsal vertebra into the sacrum (Figures 8 and 9). In the domestic fowl "the ab-

FIG. 8. The latex has been removed from the foramen pneumaticum in the proximal end of the humerus. (A portion of the cortex of the humerus has been removed to show the latex-filled lumen.) A diverticulum from the clavicular air sac communicates with the lumen of the humerus through this foramen.

FIG. 9. Cross sections of the thoracic vertebra and the lumbo-sacral mass. All of these vertebrae are filled with latex. Apparently the air that enters the cervical vertebra diffuses downward to fill the remaining vertebra: (1) spinal cord, (2) latex in a thoracic vertebra (latex fills the spaces in the vertebra, however, it does not show too well in this photograph), (3) head of femur, (4) air sac on each side of the vertebrae.

FIG. 10. Anterior surface of the lumbo-sacral mass. An air pocket (1) is located on each side of the vertebra superior to the kidney. It extends upward to the junction of the last thoracic vertebrae with the ilium. Note the air pockets filled with latex (2) between each thoracic vertebra. (Diverticula from the greater abdominal air sac pass through the sciatic foramen (3) and end blindly around the head of the femur).

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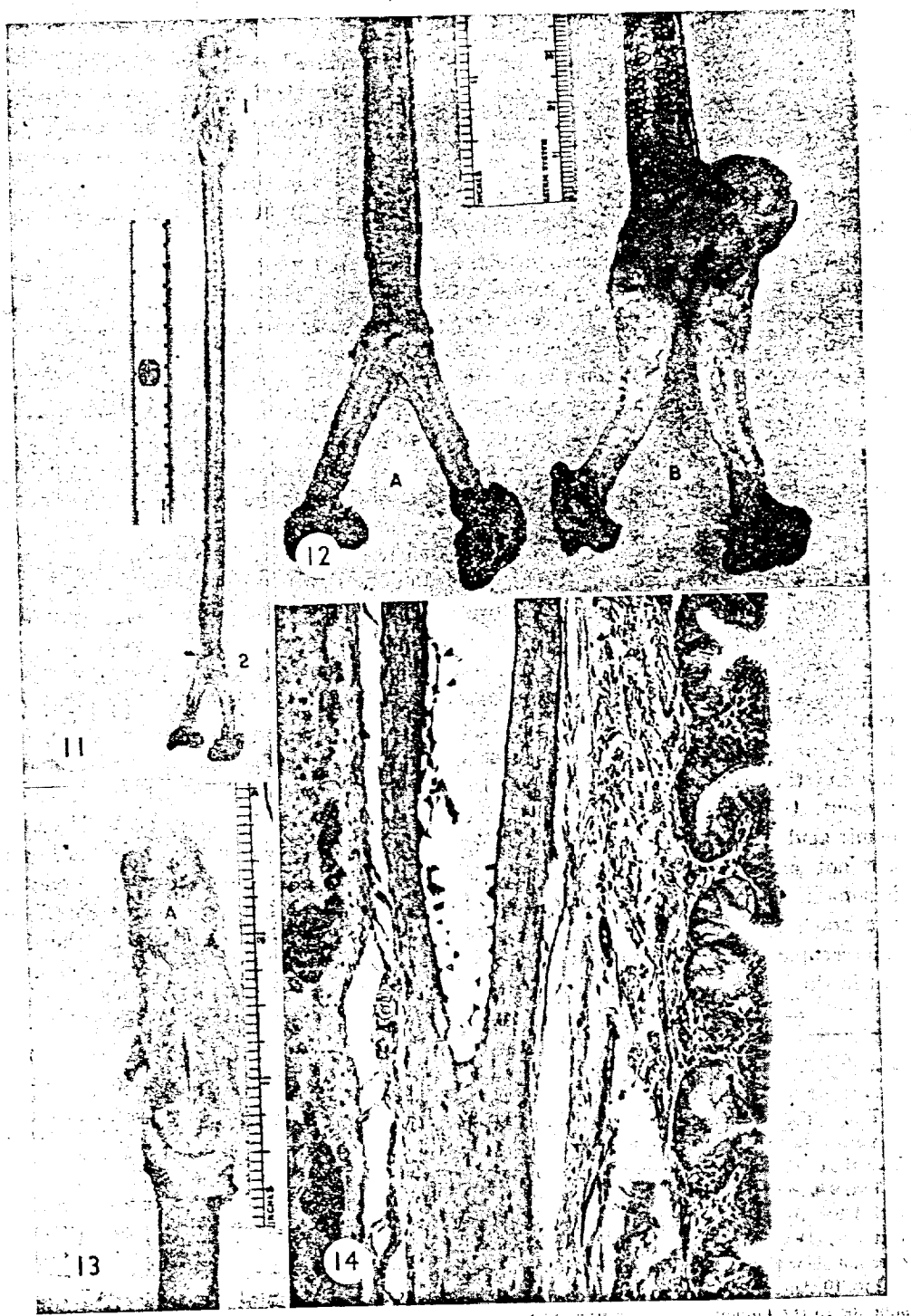

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dominal air sacs communicate with the sacrum, the coccygeal vertebrae, the iliac bones and the femur" (Kaupp, 1918). The air passing to the above 3 bones, according to Kaupp (1918), comes directly from the suprarenal extension, while the air that fills the femoral cavity comes from the femoral extension which arises from the abdominal air sac. Diverticula from the suprarenal air spaces in the duck extend through the sciatic foramen and end blindly around the head of the femur. Other diverticula extend directly from the greater abdominal air sac in the duck to the tissues around the head of the femur. The femur itself has been observed to be pneumatic in some birds (Sappey, 1847). Foust (1952), however, did not find any evidence of pneumatic cavities in the femur of a large number of birds that he studied. Sappey (1847), pointed out that the suprarenal prolongations are not present in all birds.

The bones that are always aerated in all birds, according to Kaupp (1918), "are the cervical and the dorsal vertebrae, the sternum, and the humeri. Those aerated in some birds only are the furculum, the scapulae, the vertebrae and the sternal ribs, the sacrum, the coccyx, and the femurs. Those that are never aerated are the bones of the forearm, the hand, the leg, and the foot. The Eustachian tubes furnish air to the bones of the cranium and to the upper jaw; while the lower jaw receives air from the pneumatic foramen situated upon each ramus behind the tympanic articulation, and from an air cell which surrounds the joint. Selenka states that the invasion of the bones by the air is a late development, and that in the humerus this invasion occurs after the twenty-second day in the life of the chick."

In the chicken, McLeod and Wagers (1939) have described 3 groups of recurrent bronchi, 2 of which arise from the abdominal air sacs and the other from the lateral part of the so-called anterior thoracic air sac. In the duck, only one major communication was demonstrated between each of the greater and lesser abdominal air sacs and the lungs. It is also of interest to find that in the duck the parabronchi frequently terminate as large spaces on the surface of the lung. In the chicken, McLeod and Wagers (1939) say, "May we repeat that there are no blind ends in the bronchial system of the bird. The air passages are continuous and have numerous anastomoses."

Considerable confusion exists in the literature concerning the presence or the absence of a diaphragm in birds. McLeod and Wagers (1939) consider that 2 are present: the thoraco-abdominal and the pulmonary. There are thin fibrous membranes which may be considered as diaphragms in the duck. There is also a thin membrane covering the surface of the lungs in the duck, which may be compared to the pleura in mammals.

A number of views have been expressed as to the mechanism by which air circu-

FIG. 11. Trachea from adult female White Pekin duck showing the (1) external and (2) internal larynx.

FIG. 12. Bifurcation of the trachea of an adult duck: (A) female, (B) male. The internal larynx or syrinx in the male duck is a large cartilageous-like box called the "bulla tympaniformis."

FIG. 13. The external larynx in the duck is represented by a slit-like opening in the floor of the pharynx surrounded by the glottis: (A) base of tongue showing row of papillae.

FIG. 14. Ciliated pseudo-stratified epithelial cells line the greater part of the trachea. Hematoxylin eosin stain, ×150.

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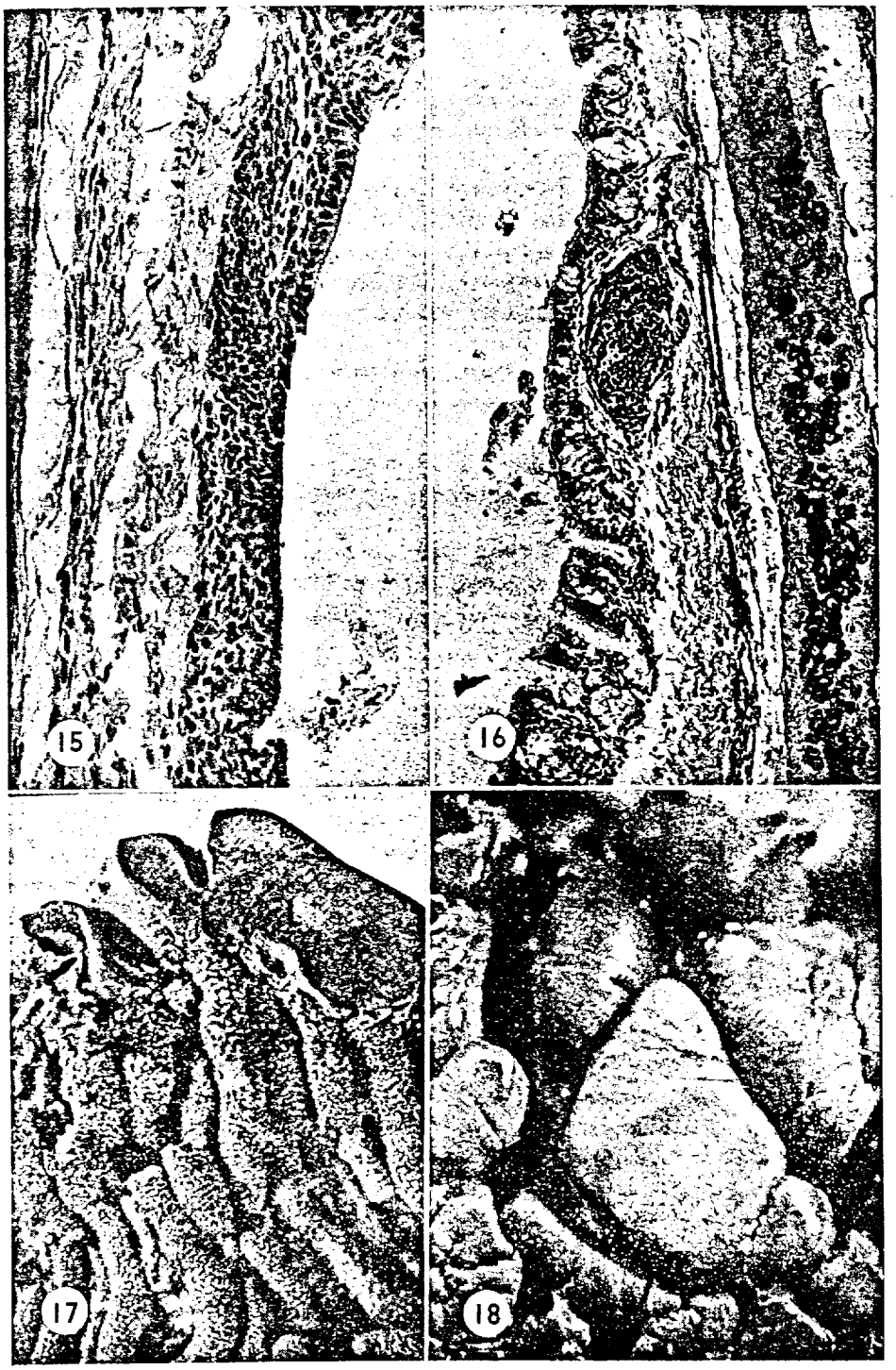

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lates through the lungs and air sacs of birds (Sappey, 1847; and Huxley, 1913). It is of considerable interest to find that the lungs of the white Pekin duck are bound to the thoracic wall by several small muscles. No doubt these play a significant role in respiration.

Sturkie (1954) has reviewed the role of the air sacs in respiration. It has been interesting to find that large quantities of fluid (270 ml. saline within an interval of 2 hours) may be put into the trachea of adult ducks and the birds show little respiratory difficulty. Apparently this fluid is rapidly removed from the respiratory tract. The mechanism of the removal of fluid and particulate matter from the lung of the duck will be reported in a subsequent study. The direct communication of some of the larger bronchi with the air sacs and the long, more or less uniform, diameter of the parabronchi frequently terminating in large spaces on the surface of the lung may be a significant factor in the mechanism of elimination of particulate material from the respiratory tract of the duck.

Lymphatic glands are absent in the duck. There are lymphatic channels in the lungs of birds that drain into the larger lymphatics which in turn communicate with the thoracic duct and then empty into the vena cava. Particulate material, when put into the trachea, usually can be demonstrated in the dilated parabronchi at the periphery of the lung and in the larger air sacs. The mechanism of phagocytosis in the respiratory tract of the duck is now being studied.

There is nothing of particular interest observed in the histologic study of the respiratory tract in the duck. It is important to know that the cilia on the epithelial cells in the respiratory tract degenerate rapidly following death. Care must be exercised in expressing an opinion on the significance of the absence of cilia from the wall of the trachea. Similarly, the absence of myelin on some of the nerve fibers in the duck might be interpreted as a pathologic process; however, the frequency in which this has been observed in the ducks used in this study would indicate that normally some of the nerve fibers are non-myelinated. Kaupp (1918) has pointed out that nerves in domestic fowls may be divided into medullated and non-medullated. The non-medullated nerves "are confined to the grav matter and to the beginnings and endings of sheath axones, all the latter being uncovered for a short distance after leaving the nerve cell body and also just before reaching their terminations."

SUMMARY

The respiratory tract in the white Pekin duck has been described. It is similar to that in the chicken. There are 9 air sacs in the duck; a single clavicular and 4 pairs, cervical, thoracic, and lesser and greater abdominal. The location of these

FIG. 15. A portion of the wall of the trachea is lined by a cuboidal pseudo-stratified layer of epithelial cells without mucin-secreting cells. Hematoxylin eosin stain, ×150.

FIG. 16. Small groups of lymphocytes occur normally in the wall of the trachea. Hematoxylin eosin stain, ×150.

FIG. 17. Tertiary or parabronchi in the lung of the duck filled with latex. The rough outer surface of these bronchi results from the failure of the latex to fill completely the surrounding air capillaries. Some of the parabronchi end in dilated spaces (1) on the surface.

FIG. 18. Latex-filled spaces on the surface of the lung represent the termination of some of the parabronchi.

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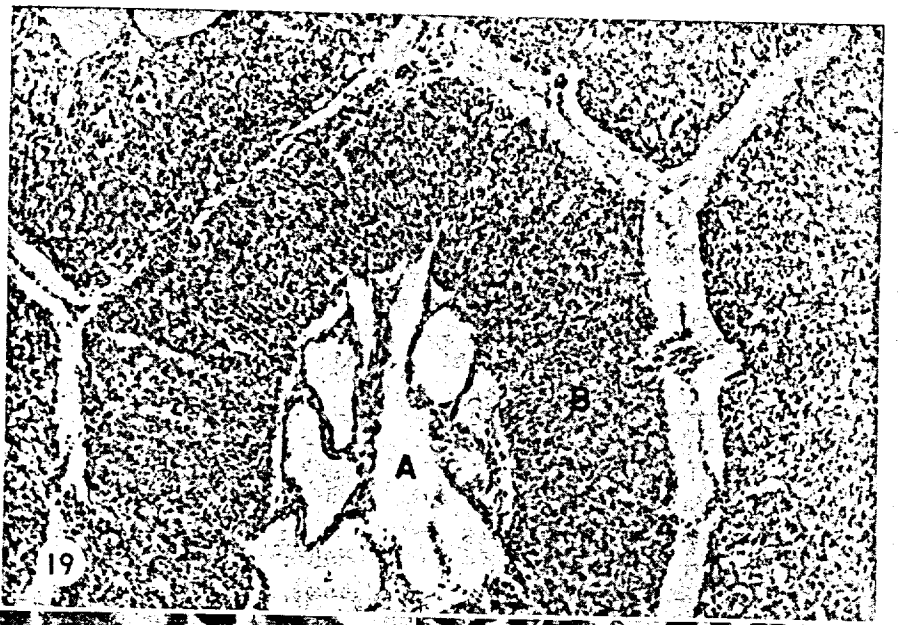

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sacs is shown in the latex-injected specimens. The gross and histologic characteristics of the respiratory tract are described and illustrated. The capillaries in the lungs are shown in a preparation injected with India ink.

Small muscles attach the lung to the thoracic wall in the duck. These muscles may be significant in respiration in the duck.

The communication of some of the larger bronchi with air sacs and the termination of many of the parabronchi in large spaces at the periphery of the lungs create a reservoir for fluid and particulate material when put into the respiratory tract through the trachea.

Latex is a good medium to inject intracheally to demonstrate the air sacs in the duck. Sometimes the bones are filled better in one bird than in another. This variation may account also for some minor diverticula being present in one duck and not in another. Such differences may represent only variations in ducks.

There are no lymph nodes in the duck; however, lymph channels are present in the lung.

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FIG. 19. A parabronchus with surrounding air capillaries: (A) parabronchus, (B) air capillaries. This is the basic respiratory unit in the lung of the duck. Hematoxylin eosin stain, ×120.

FIG. 20. Thin septa are present within the lumen of the parabronchi. These septa are covered by endothelial-like cells. Hematoxylin eosin stain, ×400.

FIG. 21. Large endothelial-like cells line the parabronchi. Hematoxylin eosin stain, ×1140.

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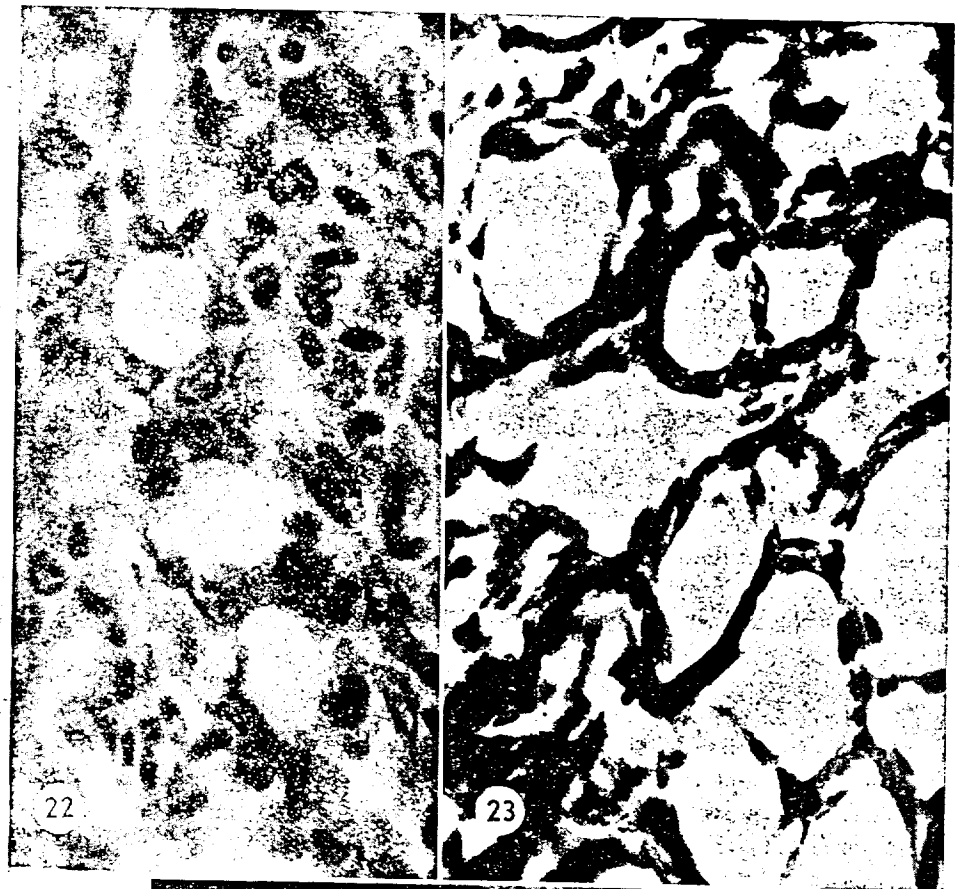

FIG. 22. The lumen of the small air capillaries in the lung also is lined by endothelial-like cells. Hematoxylin eosin stain, ×1140.

FIG. 23. Capillaries now filled with India ink surround the small air capillaries in the lung. Hematoxylin eosin stain, ×1026.

FIG. 24. Pacinian corpuscle in the wall of the trachea of the duck. Hematoxylin eosin stain, ×215.

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Source: https://www.industrydocuments.ucsf.edu/docs/zyp10000